



Z-50-RM

INSTRUCTION  
MANUAL

Z 50 R M

NJE CORPORATION

345 CARNEGIE AVENUE, KENILWORTH, N. J.



INSTRUCTION  
MANUAL

MODEL

Z-50-FM

THYRATRON REGULATED POWER SUPPLY

NJE CORPORATION  
345 CARNEGIE AVENUE  
KENILWORTH, N. J.  
CHESTNUT 1-1500







### WARNING

THIS EQUIPMENT EMPLOYS VOLTAGES WHICH ARE DANGEROUS AND MAY BE FATAL IF CONTACTED BY OPERATING PERSONNEL. EXTREME CAUTION SHOULD BE EXERCISED WHEN WORKING WITH THIS EQUIPMENT.

### CORRESPONDENCE AND ORDERING SPARE PARTS

1. Each NJE Power Supply has an identification label on the rear of the chassis which bears the model and serial number of the particular unit.
2. When requesting engineering data, reference should be made to the model and serial number and the component symbol number as shown on the applicable schematic.
3. When ordering spare parts, the information outlined in paragraph 2 should be given in addition to the NJE Part No. that appears on the parts list.



## TABLE OF CONTENTS

| <u>Paragraph</u>                        | <u>Title</u>                                    | <u>Page</u> |
|-----------------------------------------|-------------------------------------------------|-------------|
| SECTION I                               |                                                 |             |
| DESCRIPTION, INSTALLATION AND OPERATION |                                                 |             |
| 1-1                                     | GENERAL.....                                    | 1-1         |
| 1-2                                     | REFERENCE DATA.....                             | 1-1         |
| 1-3                                     | DESCRIPTION.....                                | 1-1         |
| 1-4                                     | UNPACKING.....                                  | 1-1         |
| 1-5                                     | INSTALLATION.....                               | 1-2         |
| 1-6                                     | CUSTOM MODELS .....                             | 1-3         |
| SECTION II                              |                                                 |             |
| PRINCIPLES OF OPERATION                 |                                                 |             |
| 2-1                                     | GENERAL.....                                    | 2-1         |
| 2-2                                     | OVERALL CIRCUIT DESCRIPTION .....               | 2-1         |
| 2-3                                     | CONTROL CIRCUIT.....                            | 2-3         |
| 2-4                                     | RECTIFIER CIRCUIT.....                          | 2-3         |
| 2-5                                     | CORRECTION AMPLIFIER.....                       | 2-5         |
| 2-6                                     | GRID PHASE-SHIFT NETWORK .....                  | 2-7         |
| SECTION III                             |                                                 |             |
| MAINTENANCE                             |                                                 |             |
| 3-1                                     | GENERAL.....                                    | 3-1         |
| 3-2                                     | PREVENTIVE MAINTENANCE .....                    | 3-1         |
| 3-3                                     | CORRECTIVE MAINTENANCE .....                    | 3-2         |
| 3-5                                     | COMPLETE POWER SUPPLY CHECK.....                | 3-2         |
| 3-6                                     | REGULATION CHECK.....                           | 3-6         |
| 3-7                                     | GRID PHASE-SHIFT NETWORK CHECK.....             | 3-7         |
| 3-8                                     | CORRECTION AMPLIFIER CHECK .....                | 3-8         |
| 3-9                                     | ADJUSTMENTS.....                                | 3-9         |
| 3-10                                    | SATURABLE REACTOR CURRENT ADJUST-<br>MENT.....  | 3-10        |
| 3-11                                    | THYRATRON LOAD BALANCING ADJUSTMENT             | 3-10        |
| 3-12                                    | OUTPUT VOLTAGE CONTROL RANGE<br>ADJUSTMENT..... | 3-10        |



## SECTION I

## DESCRIPTION, INSTALLATION AND OPERATION

## 1-1. GENERAL.

The NJE ET-Series and Z-Series of Thyatron Power Supplies are designed for use in applications requiring a well regulated and stable source of dc voltage at high values of current.

## 1-2. REFERENCE DATA.

The electrical characteristics of the Power Supply are given in Table 1 at the end of this section.

## 1-3. DESCRIPTION.

The NJE ET-Series and Z-Series of Thyatron Power Supplies are identical except for the size of the output filter capacitance. The zero-lag feature obtained as a result of this larger output capacitance holds the output voltage within the regulated region for all specified step changes of line and load. These Power Supplies come in four different types as follows:

- Cabinet without meters - C
- Cabinet with meters - CM
- Rack mounted without meters - R
- Rack mounted with meters - RM

All operating controls, and one set of output terminations when the output does not exceed 30 amperes, are located on the front panel. The balance of the parts are located on separate chassis and the main frame. The input and main output terminals are located at the rear of the equipment as are the main line and control circuit fuses.

## 1-4. UNPACKING.

The complete shipment consists of a small carton containing the thyatron tubes, and one or more large cartons or crates containing the Power Supply. All cartons should be opened immediately upon receipt and the contents inspected for shipping damage. The Power Supply was checked electrically and mechanically before it left the factory, and is warranted to be in perfect operating condition. This guarantee does not cover possible damage incurred during shipment. Therefore, any evidence of mishandling, such as broken, deformed, or missing parts, should be brought to the attention of the transportation company and a claim should be entered. Open the cabinet doors and inspect all components and wiring, both on the chassis and panel, as well as the mechanical condition of the housing.



After the equipment has been placed in its operating location, unpack the thyatron tubes and install them in the appropriate sockets or holders. Unwrap the thyatron anode caps and untie their leads; connect each anode cap to the tube as designated on the top of the cap.

#### CAUTION

In connecting or removing the plate caps, take care that they are pushed on and pulled off without twisting in either direction.

#### 1-5. INSTALLATION.

The cabinet model equipment requires no installation outside of the connection of a good ground to the appropriate terminal at the rear of the equipment.

The rack model is notched for installation in a standard, 19-inch, relay rack. It should be securely fastened in place and a good ground connected to the appropriate terminals at the rear of the cabinet.

To permit monitoring and regulating the dc output voltage without introducing an error due to voltage drop in the cable connecting the supply and the load, the input of the correction amplifier has been brought out to the Positive Sensing and Negative Sensing terminations at the rear of the equipment. These must be connected through separate sensing leads directly to the load, observing correct polarity. A 20-gauge, stranded, and shielded wire is recommended. While it is possible to jump the sensing leads directly to the positive and negative output terminations of the supply, so doing will cause the load leads to be included as part of the external load, and the actual voltage at the remote load will vary accordingly with changes in load current.

#### CAUTION

All ET- and Z-Series Power Supplies which utilize three phases input power are phase sensitive. This means that the equipment when installed at the customers location will have to be connected to the 3-phase input line (at terminals 1, 2, 3 and 4 of TB301) in the same sequence used at the manufacturer's plant where final test and adjustment was made. Before connecting the Power Supply to the 3-phase line, the phase relationship must be checked with an oscilloscope. Connect one phase of the 3-phase line to the oscilloscope External Sync terminals, making certain the neutral leg is



connected to the common or negative terminal. Connect one phase of the 3-phase input line to the vertical input terminals of the oscilloscope, making certain the neutral leg is connected to the common or negative terminal. Lock the waveform so that only one full cycle appears on the oscilloscope screen, and that the positive peak is on the left side of the screen. Make note of the vertical line on the oscilloscope scale at which the positive peak occurs; this is the A-phase. Disconnect this phase and connect the other two phases, one at a time, without touching the sync control. The positive peak of the B-phase will appear to the right of the vertical scale line previously noted (approximately midscale), and the positive peak of the C-phase will appear to the right of the B-phase peak (on the right side of the screen). Now the 3-phase input line can be connected to terminal board TB301 as shown on the schematic diagram.

The input and output connections are normally made at the rear of the chassis. Additional output terminals are provided on the front panel for convenience in bench use when the output current does not exceed 30 amperes. The output of the supply can be connected for either polarity and can be floated as much as 500 volts (peak) above or below chassis ground. However, the most stable operation will be obtained when one of the two output terminals (POS or NEG) is connected to the chassis ground (GRD) either by a jumper or through a 0.1 microfarad, 600-volt capacitor.

In those models in which two cabinets or two rack-mounted chassis are employed, the interconnecting cable will be found in the main unit. Connect this cable to the appropriate terminals on the second unit.

#### 1-6. CUSTOM MODELS.

This manual also covers custom models incorporating special features and/or special output voltages and currents. In these cases Table 1, covering the standard ET and Z Series Electrical Specifications, are omitted; and the electrical specifications and circuit variations are given in Table 1 for the particular model.



## TABLE 1. ELECTRICAL SPECIFICATIONS

MODEL Z-50-RM

## THYRATRON REGULATED DC POWER SUPPLY

|                     |                                                                                                                                                                                                                                                                                  |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| INPUT:              | 105 to 125 volts, 60 cycles per second, single phase, approximately 15 amperes, 70 percent power factor at full load.                                                                                                                                                            |
| OUTPUT:             | Continuously variable by front panel control from 64 to 160 volts dc at 0 to 4 amperes.                                                                                                                                                                                          |
| RIPPLE:             | ET-Series: less than 1 percent rms at any output voltage and current within rating.<br><br>Z-Series: less than 0.1 percent rms at any output voltage and current within rating.                                                                                                  |
| REGULATION:         | Line: will not exceed 0.1 percent or 50 millivolts, whichever is greater, for $\pm 10$ percent line voltage change at constant load.<br><br>Load: will not exceed 0.1 percent or 50 millivolts, whichever is greater, for 0 to 100 percent load change at constant line voltage. |
| POLARITY:           | Output can be floated up to 500 volts peak off ground. Either output terminal may be grounded to chassis.                                                                                                                                                                        |
| TRANSIENT RESPONSE: | ET-Series: transient response is 75 milliseconds for 63 percent recovery from maximum displacement with 25 percent step change in load.<br><br>Z-Series: transient response remains within $\pm 1$ percent of nominal output value with 25 percent step change in load.          |



## SECTION II

### PRINCIPLES OF OPERATION

#### 2-1. GENERAL.

The ET Series and Z Series Thyatron Power Supplies provide a source of well-regulated dc power. The two types of Supplies are identical except for the value of the output capacitance which is considerably larger on a Z Series unit in order to provide the specified zero lag.

The circuits that go to make up an ET Series or Z Series Power Supply are always the same. A custom thyatron supply will include these circuits either modified or added to in order to fulfill the customer's specifications. These circuits include the Control Circuit, the Rectifier Circuit, the Grid Phase-Shift Network, and the Correction Amplifier. The Control and Rectifier Circuits appear on one schematic and separate schematics cover the Correction Amplifier and Grid Phase-Shift Network. These schematics will be found at the rear of the manual.

The Rectifier Circuit employs one of three configurations namely: single-phase, full wave; three-phase, half wave; or three-phase, full wave. The configuration used is dependent upon the output voltage and current requirements.

#### 2-2. OVERALL CIRCUIT DESCRIPTION.

The rectifier circuit converts the ac input voltage into pulsating dc voltage which in turn is changed to a smooth dc output voltage by the filter network. This dc output voltage is affected by fluctuations in the ac input voltage and the dc load current. To maintain a steady dc output voltage despite these variations, a feedback circuit is employed. In a thyatron-regulated power supply this feedback circuit differs from that encountered in the conventional series-tube regulated supply in that the flow of current is varied within the rectifier, rather than in a subsequent series element. By shifting the phase of a small ac voltage applied to the grid of the thyatron tube with respect to the phase of the ac plate voltage, the control signal determines the firing point at which the thyatron tubes will start to conduct. Varying the firing point earlier or later in the positive half-cycle of the ac plate voltage results in an increase or decrease in the average current supplied to the load and so raises or lowers the output voltage.

The feedback circuit is composed of a sensing voltage divider, the Correction Amplifier and a number of Grid Phase-Shift Networks. In voltage regulated equipments, the Correction Amplifier is connected through the sensing voltage divider to the sensing terminals of the Power Supply which in turn are connected to the load, see figure 2-1. In current regulated equipments, the sensing voltage divider is shunted by a fixed resistor in the return



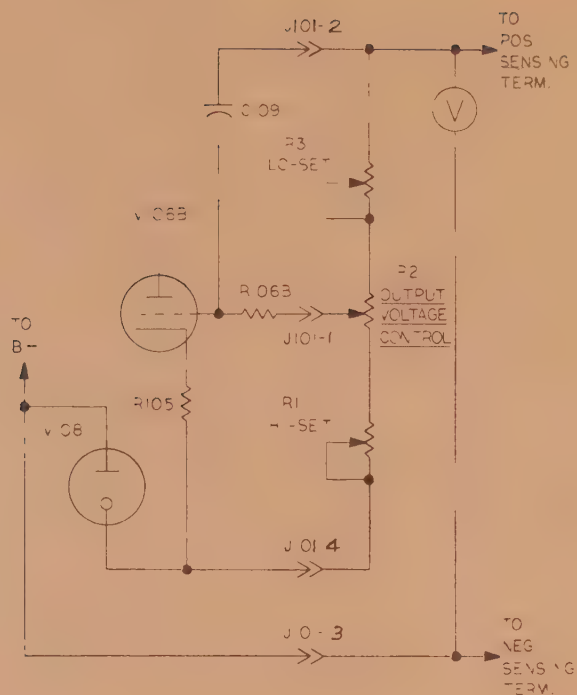


Figure 2-1. Correction Amplifier Input Circuit, Regulated Supply

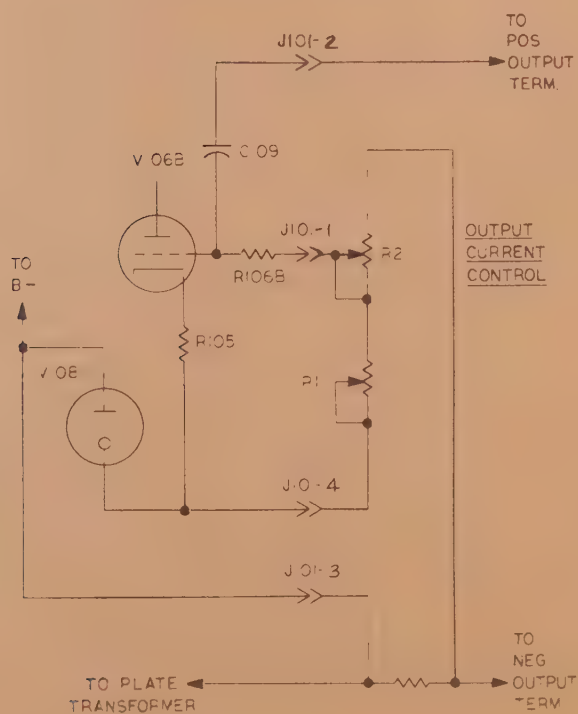


Figure 2-2. Correction Amplifier Input Circuit, Current Regulated Supply



leg of the Supply, see figure 2-2. The amount of current being drawn determines the voltage drop across this resistor and this voltage is impressed across the sensing voltage divider and the Correction Amplifier input. In either case, minor variations in the load voltage (current) appear in a magnified form at the output of the Amplifier. This output is used to control through the Grid Phase-Shifter Networks the phase of the voltage applied to the grids of the thyatron tubes.

This type of error correction configuration can never completely compensate for a change in load voltage regardless of the degree of error amplification used. However, the regulation for no load to full load variation is consistently maintained within the specified percentage or magnitude.

### 2-3. CONTROL CIRCUIT.

The Control Circuit for the single-phase and three-phase Supplies is the same except that in the three-phase units three fuses, F302-1, -2 and -3, protect various circuits outside of the rectifier plate transformer in lieu of a single fuse F302 which performs this function in the single-phase Supplies.

When AC switch S1 is set to the ON position, indicator DS1 is lighted, 60-second time delay relay K1 is energized, and the 115-volt (or 208-volt, three-phase) input is fed to the Grid Phase-Shift Network(s). With the elapse of the 60-second time delay period, relay K1 contacts close and energize TIME DELAY OVER indicator DS2. When DC switch S2 is closed, indicator DS3, line relay K301 and the Correction Amplifier are energized.

The Control Circuit also includes three potentiometers which form the sensing voltage divider and serve as the output control of the Power Supply.

### 2-4. RECTIFIER CIRCUIT.

The Rectifier Circuit can take one of three configurations, namely: single-phase, full wave; three-phase, half wave; or three-phase, full wave. The configuration used is dependent upon the output current and voltage requirements. All three circuits employ the following basic elements:

- a. Filament and plate transformers to step down and/or step up the ac input voltage to the required operating values.
- b. Thyatron rectifiers to change the ac voltage output from the plate transformer to pulsating dc voltage.
- c. Filter network to reduce the pulsations and furnish a smooth dc voltage to the external load.

As thyatron tubes are subject to damage if the plate voltage is applied before the filament has reached operating temperature, separate filament and



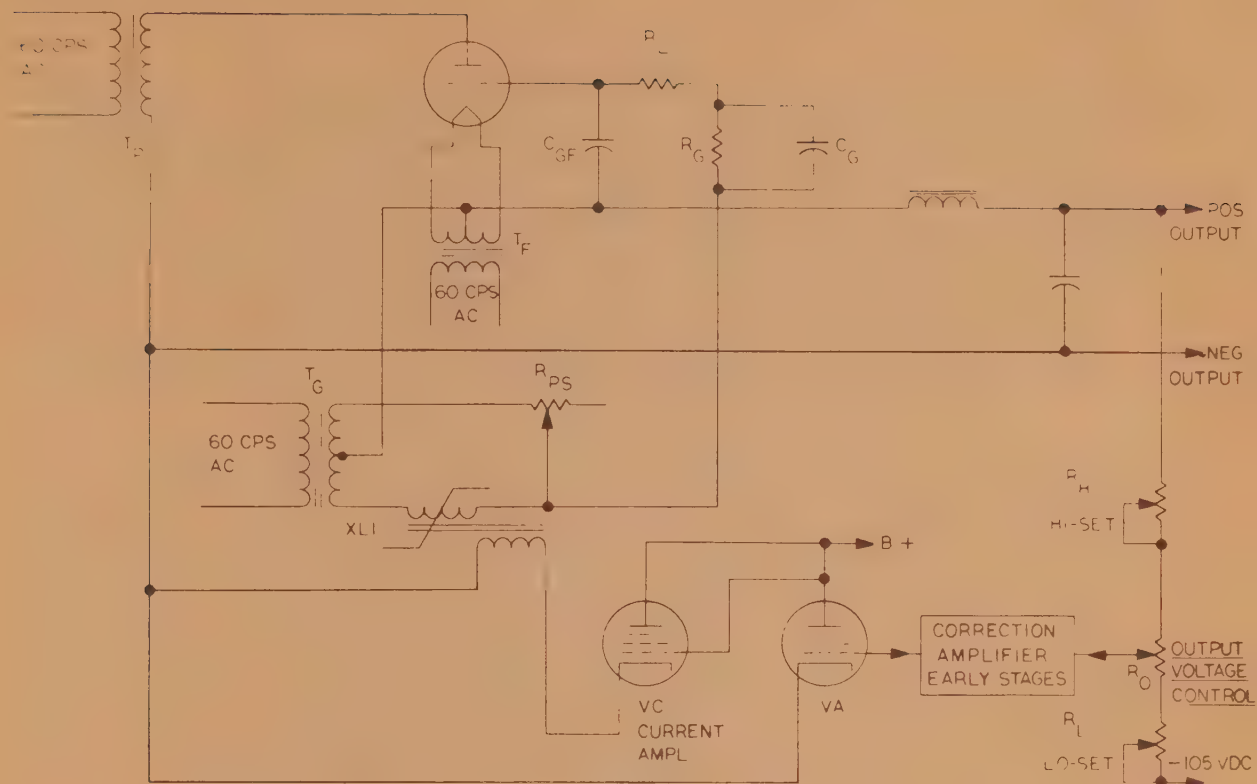


Figure 2-3. Simplified Grid Control Circuit Diagram

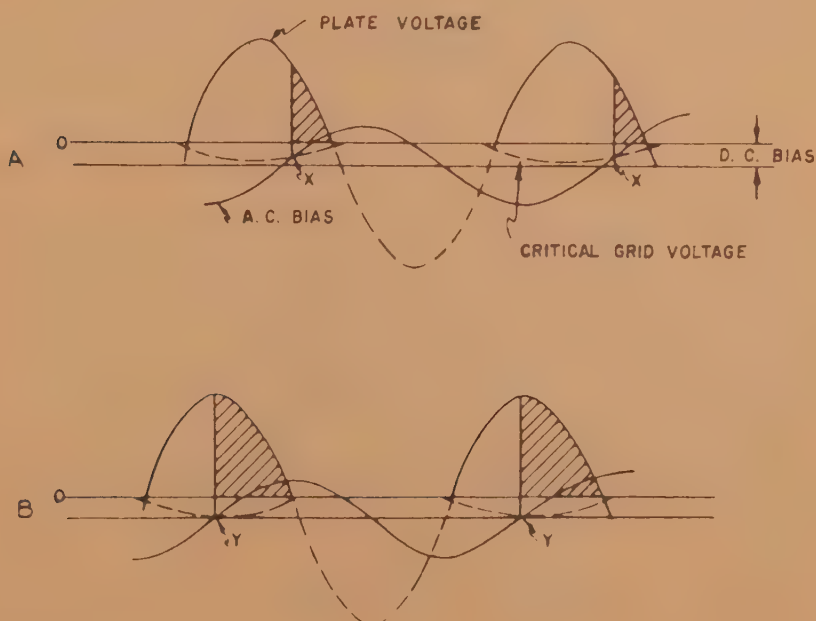


Figure 2-4. Thyratron Rectifier Waveforms



plate transformers are used. Thyatron filament transformer T302 is energized as soon as the AC switch is operated. Transformer T301 which supplies ac to the thyatron plates is connected to the ac input line through line relay K301 when 60-second time delay relay K1 has closed and DC switch is operated. It should also be noted that time delay relay K101 in the Correction Amplifier interposes a 10-second delay after the application of plate voltage, before the grid voltage is applied to the thyatron tubes. This is done so that the heater warm-up of the Correction Amplifier results in a gradual phase shift of the thyatron grid voltage and brings the dc output voltage of the Power Supply to the desired level without overshooting.

The filter network comprises two choke-input type filter stages; L301 and C301 is the first, and L302 and C302 the second. The filter network is shown on its own schematic. The number of capacitors in each section varies and each group of up to five capacitors is protected by a fuse. It is in the second filter that the difference between the ET-type and Z-type units is apparent. To obtain the zero lag for the Z-type units a large number of capacitors are connected in parallel. The output of the second filter is fed to bleeder R301, and to the dc output terminals via ammeter M2, located on the front panel. The output voltmeter is also on the front panel and is connected to the sensing terminals, thus measuring the voltage at the load.

It should be noted that the ac for the Grid Phase-shift Network and its associated thyatron tube filament is obtained from the same phase of the ac input line in the case of the three-phase units. A single Correction Amplifier is employed to feed all the Grid Phase-Shift Networks regardless of the number of rectifier phases employed. Where more than one Grid Phase-Shift Network is used, the inputs are connected in series across the Correction Amplifier output.

## 2-5. CORRECTION AMPLIFIER.

Variations in the ac input line and/or external load of the Power Supply cause variations in its dc output voltage. It is the function of the Correction Amplifier to detect such variations the instant they begin, and to institute corrective action to prevent the variation from developing. In order to do this, the amplifier must be extremely stable and must have a well regulated source of reference voltage against which it can compare the dc output voltage of the equipment. The difference of the Power Supply output voltage and the reference voltage is a measure of the degree of deviation (referred to as the "error" voltage) which is used by the amplifier in determining the amount and rate of correction needed to retain the desired output voltage.

To assure maximum stability and minimum external interference, the amplifier incorporated its own regulated source of dc power. Transformer T101, rectifier V101, and capacitor C101 provide dc voltage through resistor R101 to gaseous voltage regulator tube V103, which furnishes regulated 150 volts dc to the plates of tubes V105A, V106A and B, and V107. Transformer



T101, rectifier V102, and capacitor C102 supply dc voltage through resistor R102 to gaseous voltage regulator V104 which provides regulated -150 volts dc as the return connection for the cathode circuits of tubes V105 and V106. The negative lead of the +150-volt dc circuit and the positive lead of the -150-volt dc circuit are connected to the center-tap of the high voltage winding of transformer T101. Gaseous voltage regulator tube V108 is connected in series with resistor R114 across the output of regulator tube V104. The regulated 85 volts developed across tube V108 provides the reference voltage for differential amplifier tube V106.

Differential amplifier tube V106 is a twin-triode, one grid and cathode of which is connected across the -85V regulated reference voltage as described above. The other grid (pin 7) is connected to the arm of potentiometer R2 which is part of the sensing voltage divider, see figure 2-1. The voltage at the load appears across the sensing voltage divider, and a selected fraction of this voltage is impressed on the grid of tube V106B. Thus, any variation in load voltage results in a variation of the voltage impressed on the grid of this tube. Since both sections of V106 have a common cathode resistor and the 'A' section grid potential is held fixed, variations in the grid-to-cathode voltage of the 'B' section will cause equal and opposite changes at the plates of this tube. The plates of V106 are coupled to the B+ line through resistors R107 and R110 which with resistor R108, R109, R111, and R112 form a voltage divider between the + 50-volt and -150-volt lines. This enables the plots of V106 to be direct-coupled to amplifier tube V105A, one directly to its grid, pin 2, and the other through cathode follower V105B to its cathode, pin 7. The grid and cathode are tapped off the voltage at mean values that provide an ample plate-to-cathode voltage drop in V105A, making it unnecessary to operate this tube from a separate elevated voltage source. Cathode follower V105B serves to match the high output impedance of the plate of V106B to the low impedance of V105A cathode. Capacitors C105 and C106 shunt resistors R108 and R111 to speed up the transient response of the ac "error" signal. Capacitors C103, C104, and C108 and their associated resistors constitute a frequency and phase-shift network which prevents the feedback around the correction loop from becoming positive and causing the system to break into oscillation. Potentiometer R113 permits modifying this network, during preliminary adjustment of the Power Supply, to achieve stable operation under the rated operating conditions. This potentiometer normally requires no further adjustment once the correct setting has been established except when tubes or other circuit components are replaced. The output of Amplifier V105A is coupled directly to the grid of triode-connected pentode V107. This tube acts as a cathode follower, its load consisting of the control winding of saturable reactor XL201 in the grid phase-shift network. When three grid phase-shift networks are used, the control windings are connected either in series or parallel and thus are controlled simultaneously by tube V109.

Time delay relay K101 is connected in series with heater of tube V107 to prevent output voltage overshoot when the Power Supply is turned on.



It delays the application of control voltage to the grid phase-shift network until the balance of the tubes in the amplifier circuit have reached operating temperature. Early models of both the ET-Series and Z-Series did not employ K101.

## 2-6. GRID PHASE-SHIFT NETWORK.

This network provides the phase-shift voltage impressed on the grids of the thyatron tubes to control their firing point and in turn the magnitude of the output voltage. Either one of two types are used; the half wave when a three-phase, half wave rectifier configuration is employed; or the full wave when the single-phase, or three-phase, full wave rectifier configuration is employed. The operating principles are the same for both networks. The only difference between the two types is the addition of a push-pull output transformer, and additional capacitor and resistors in the full wave type.

A simplified grid control circuit diagram is given in figure 2-3. The primaries of transformers TP and TG are in phase being energized from the same ac source. The secondary of TG feeds the phase-shift network comprising saturable reactor XL1 and rheostat Rps. The output of this circuit is taken from the center tap of the transformer and the junction between reactor XL1 and rheostat Rps in the case of the half-wave type, and from the secondary of the push-pull transformer in the case of the full-wave type. The primary of the push-pull transformer is connected in the same way as the half-wave output of the phase-shift circuit and provides the push-pull output required for full wave operation. The parallel rc network comprising RG and CG in the grid side of the output provides a dc bias for the thyatron by grid rectification; and the ac control signal from the phase-shift circuit is superimposed upon this dc bias.

For any given value of thyatron plate, there is a corresponding value of negative grid voltage which will just prevent the thyatron from conducting. This value is known as the critical grid voltage and is shown as a dotted curve in B of figure 2-4 for the entire positive half-cycle of the plate voltage. If the grid voltage becomes less negative than the indicated critical value at any instant during the positive half-cycle, the tube will fire at that instant and conduct throughout the remainder of the positive plate voltage interval.

Ignoring the effects of the ac signal, the dc (grid rectification) bias holds the grid sufficiently negative to maintain the tube in a continually cut off condition. When the ac signal voltage is superimposed upon this dc bias, the resultant bias fluctuates above and below the nominal dc value as shown in figure 2-4A. At some point during the positive half-cycle of the plate voltage, the voltage on the grid becomes less negative than the critical grid value at that point and the tube fires. This instant is indicated at X where the positive-going bias voltage curve intersects the critical grid voltage curve. The thyatron conducts throughout the remainder of the half-cycle and is extinguished when the plate voltage drops to approximately zero.



By shifting the phase of the ac grid control voltage with respect to the plate voltage, the firing point can be changed to a point earlier or later in the cycle, causing the thyatron to conduct during a greater or lesser fraction of the half-cycle. Figure 2-4B shows the ac grid control curve intersecting the critical grid voltage curve at an earlier point in the plate voltage half-cycle (point Y). Comparison of figures 2-4 A and B shows that shifting the ac grid control voltage to the right decreases the interval of conduction of the tube. The shaded areas of the plate voltage curves indicate the period during which the thyatron conducts, and are representative of the relative amount of power furnished to the load in each case. Thus, the greater the lag of the grid voltage with respect to the plate voltage, the smaller will be the conduction period. This principle is used to automatically control the output voltage as outlined below.

Referring to figure 2-3 we find the voltage drop across the external load is connected through the sensing leads across a voltage divider consisting of resistors RH, RO, and RL. The input to the correction amplifier is determined by the setting of the arm of potentiometer RO. The grid potential of final voltage amplifier tube VA, in the correction amplifier, determines the cathode current of current amplifier tube VC since the plate of tube VA is direct-coupled to the control grid of tube VC. The cathode current of tube VC flows through the control winding of saturable reactor XL1 in the phase-shifting network. Since the inductance of reactor XL1 and the resistance of rheostat Rps together determine the degree of phase shift occurring in ac grid voltage at the thyatron grid, and since the current through the control winding of saturable reactor XL1 in the phase-shifting network. Since the inductance of reactor XL1 and the resistance of rheostat Rps together determine the degree of phase shift occurring in ac grid voltage at the thyatron grid, and since the current through the control winding of reactor XL1 determines its inductance, it can be seen that the grid voltage of tube VC determines the conduction interval of the thyatron. Thus, by adjusting potentiometer RO, the firing point can be adjusted from zero to maximum output. Since the position of the firing point determines the interval during which the thyatron supplies energy to the filter, it determines the total charge per cycle applied to the filter capacitance. With a constant external load discharging the capacitor, and the thyatron applying a periodic charge to the capacitor, an equilibrium is established at a particular value of output voltage. When the load resistance decreases, the output voltage of the Power Supply tends to decrease because of the greater current drain. This causes the control grid of amplifier tube VA to become more negative, in turn increasing the current drawn by tube VC through the control winding of saturable reactor XL1. The inductance of reactor XL1 decreases, shifting the phase of the ac voltage applied to the grid of the thyatron so as to cause the tube to conduct for a greater portion of the positive half-cycle of the plate voltage. The increased charging period compensates for the increased drain on the Power Supply, and the output voltage remains essentially constant. A tendency of the output voltage to



increase is counteracted by a reverse series of actions resulting in a decrease in the thyatron conduction interval.

Regulation theory shows that, if the correcting action results only from the "error" sensed by monitoring the output, the compensation can never be complete, regardless of the error amplifier gain. The amplification system is a closed loop, and an input voltage change produces an output voltage change which in turn is fed back to the input in such a way as to counteract the original change at the input. Thus, should the "error" be reduced to zero, the compensation would likewise disappear. This would imply that an absolutely steady output voltage can be maintained with no compensation, which is obviously untrue. Increases in the gain of the correction amplifier permit it to achieve equilibrium with less residual error, but a small error must always remain, in a true proportional regulator.

The foregoing material outlines the functioning of a circuit including one thyatron tube. It can be applied without change to either the single-phase, full wave (two-tube), three-phase, half wave (three-tube), or three-phase, full wave (six-tube) configurations. The plate and grid transformers in each circuit are correctly phased so that each thyatron conducts in its turn, and the repetitive sequence of current pulses is smoothed and filtered by the common choke-input filter network. The correction amplifier in the Power Supply simultaneously controls the degree of phase shift of the ac grid voltage on all of the thyatron tubes, but the ac signal itself is generated at each grid in proper sequence to control all phases of the output. To assure equal conduction and proper commutation between the thyatrons, the resistance element of the phase-shift circuit is adjustable.



## SECTION III

### MAINTENANCE

#### 3-1. GENERAL.

Care should be exercised to prevent the accumulation of dust and dirt in the equipment. An adequate natural flow of clean, fresh air, free of corrosive gases, should be maintained at all times the equipment is in operation. Sudden changes in temperature and humidity should be guarded against. While the equipment will operate over a wide range of physical conditions, every effort should be made to maintain the temperature of the room over zero degrees C and below plus 45 degrees C with a minimum of humidity.

#### 3-2. PREVENTIVE MAINTENANCE.

A well-organized maintenance program will materially aid dependable operation and reduce 'down time' of the equipment to a minimum. A maintenance program, if followed, will often forestall trouble and breakdowns, where the trouble is at once clear, to general overall wear and deterioration of parts over a long period of time. Particularly guard against the latter condition by conducting complete inspections at regular intervals. It is suggested that the equipment be tested shortly after it is put into operation for the first time, and the results be recorded as a reference for comparison with subsequent weekly tests. In addition to voltage measurements, a check of the voltage at the output of the rectifier and at the output terminals should be made with an oscilloscope, or if none is available, an ac voltmeter in series with a dc blocking capacitor.

The following procedure is recommended at intervals of 3 to 6 months:

- a. Disconnect power supply from input line.
- b. Remove cabinet, covers and/or bottom plate, and inspect the circuitry for dust or dirt deposits (which should be blown or brushed away) and remove foreign objects, such as hardware or small components, which may have fallen in through the ventilating spaces during bench use. Look for signs of overheating, which may indicate overloading due to misuse or malfunctioning of a part.
- c. Check that chassis-mounted components are securely held in place by their clamps or brackets. Wipe them with a soft cloth to remove heavy dust deposits.
- d. Check knobs, binding posts, terminal strips, and fuse extractor clamps for looseness. Tighten carefully, preserving alignment.
- e. Check calibration and zeroing of meters, if used.
- f. Check that fuseholders contain the correct value fuses. Do not overfuse!



g. Replace cabinet, covers and/or bottom plate, and check operation of instrument as outlined in step h.

h. Rough regulation check: Operate supply at nominal line voltage. Set supply to approximately midrange. Monitor output with external meters, unless it has panel meters. A long-scale external voltmeter is recommended, under the circumstances, for a meaningful check. This meter should read at least midscale at midrange of the supply, so that changes of the order of the nameplate regulation are discernible. Alternately connect and disconnect an external load of appropriate rating and resistance to draw full load current for the output level selected observing the voltmeter for steady-state changes. If the output varies more than the product of specified regulation and output voltage, a detailed check of the unit should be made.

i. Ripple check: Check output ripple by means of a low-range ac voltmeter coupled to the dc output by means of a 0.1 microfarad capacitor. If excessive, check the capacitor bank for blown fuses or "open" capacitors. Examination of the waveform on oscilloscope at the input terminal of the filter choke should show a typical thyatron firing pattern for each rectified phase. A notch in the waveform indicates a defective choke, while absence of any phase indicates a defective rectifier. The correct type of pattern will be found in figure 3-1.

### 3-3. CORRECTIVE MAINTENANCE.

#### WARNING

THIS EQUIPMENT EMPLOYS VOLTAGES WHICH ARE DANGEROUS AND MAY BE FATAL IF CONTACTED BY OPERATING PERSONNEL. EXTREME CAUTION SHOULD BE EXERCISED WHEN WORKING WITH THIS EQUIPMENT.

A failure in the Power Supply will be evidenced in one of the following ways:

- a. abnormal output voltage level (too high or too low)
- b. complete loss of output voltage
- c. erratic fluctuations in the output voltage
- d. oscillation
- e. failure to regulate correctly
- f. abnormally high output ripple.

These symptoms are treated individually in the following paragraphs. In each case, the wave form should be checked at the output terminals and at the input to the first filter choke, L301. These two points will reveal the majority of faults and their sources by simple inspection.

### 3-5. COMPLETE POWER SUPPLY CHECK.

The output of the Power Supply is a steady dc voltage with a small amount of ripple, as specified in Section 1, superimposed thereon.





Figure 3-1. Rectifier Output, Representative Waveforms

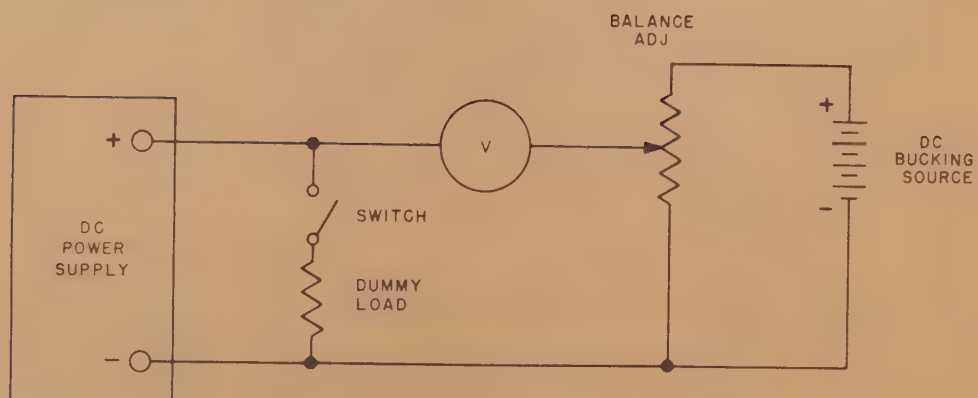


Figure 3-2. Precise Regulation Check



An oscilloscope connected to the dc output terminals will display a uniform ac waveform composed of 120 cycles (single-phase, full-wave circuit); 180 cycles (three-phase, half-wave circuit); or 360 cycles (three-phase, full-wave circuit), plus higher harmonics.

The waveform at the input to the filter circuit shows the combined output of the thyatron rectifiers. Normally, this waveform comprises a series of identical modified-half-sine wave loops of the general form shown in figure 3-1. The shape of the wave will depend upon the amount of current drawn by the load and the waveshape changes with decreasing load as shown. With the oscilloscope sweep adjusted to display several cycles of the line frequency, a normal equipment will produce a continuous train of pulses identical in shape, amplitude and period. Departures from this pattern indicates a defective circuit, and the form of departure is indicative of the source of trouble as outlined in the following table. When a spare Correction Amplifier and Grid Phase-Shift Network are available, it will materially cut trouble-shooting time to substitute the spares if either of the components are thought to be defective. The defective component can then be checked after the Power Supply is in operation.

TABLE 3-1. TROUBLESHOOTING CHART

| <u>Symptom and<br/>Waveform at<br/>First Choke</u>                                                           | <u>Possible Cause</u>                                                                                                                     | <u>Remarks</u>                                                                                                                                                                                                                                                         |
|--------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Abnormally high dc output voltage level. Normal waveform.                                                    | Defective Correction Amplifier.<br>Open bleeder resistor.<br>Defective choke L301.<br>Defective sensing voltage divider.                  | Check dc output waveform. If ripple is excessive, check for open bleeder or shorted choke. If ripple is normal, replace Correction Amplifier with spare, if available. Check sensing voltage divider R1, R2 and R3. Check for poor connection in amplifier connectors. |
| Abnormally high dc output voltage level. One or more phases show excessive conduction angle on oscilloscope. | Defective thyatron tube(s).<br>Defective Grid Phase-Shift Network.<br>Defective thyatron grid bypass capacitor(s) C303, C304 and/or C305. | Adjusting phase-shift potentiometer (R201) controlling defective phase. Check thyatron grid bypass capacitor located at tube socket. If no change, replace Phase-Shift Network of defective phase. Replace thyatron tube(s).                                           |



TABLE 3-1. TROUBLESHOOTING CHART - Continued

| Symptom and<br>Waveform at<br>First Choke                                                                                   | Possible Cause                                                                                                                                                                   | Remarks                                                                                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Complete failure of<br>dc output. Wave-<br>form normal.                                                                     | Defective choke.                                                                                                                                                                 | Check choke for open<br>circuit.                                                                                                                                                                                     |
| Complete failure of<br>dc output. Wave-<br>form absent.                                                                     | Defective Correction<br>Amplifier.<br>Loss of filament and/or<br>plate circuit primary<br>power.<br>Defective filament or<br>plate transformer.                                  | Check for poor connection<br>in amplifier connectors.<br>Check amplifier operation.<br>Check AC switch, all ac<br>fuses, and relay K301.<br>Check input and output<br>voltages of transformers<br>T301 and T302.     |
| Erratic fluctuation<br>of dc output voltage.<br>Erratic waveform<br>variations occur<br>simultaneously on<br>all phases.    | Defective Correction<br>Amplifier.<br>Defective filter capacitor<br>and/or choke.                                                                                                | Check amplifier operation.<br>If amplifier is good, dis-<br>connect capacitor banks<br>one by one (by removing<br>bank fuse). If capacitor<br>banks are good, check choke.                                           |
| Erratic fluctuation<br>of dc output voltage<br>with variations in<br>waveform of one<br>phase only.                         | Defective thyatron tube.<br>Defective grid bypass<br>capacitor C303, C304, or<br>C305.<br>Defective Grid Phase-<br>Shift Network.<br>Defective filament or<br>plate transformer. | Check input and output volt-<br>ages of transformers T301<br>and T302. If no fluctuations<br>present, replace thyatron<br>tube and associated grid<br>bypass capacitor.<br>Check or replace Phase-<br>Shift Network. |
| DC output voltage<br>fluctuates at a<br>cyclic rate. Wave-<br>form fluctuations<br>occur simultaneous-<br>ly on all phases. | Defective Correction<br>Amplifier.                                                                                                                                               | Adjust potentiometer R113,<br>in Correction Amplifier, to<br>suppress fluctuation. Check<br>amplifier operation.                                                                                                     |
| DC output voltage<br>fluctuates at a<br>cyclic rate. Wave-<br>form fluctuations<br>occur on one phase<br>only.              | Defective thyatron tube.<br>Defective Grid Phase-<br>Shift Network.<br>Defective grid circuit by-<br>pass capacitor.                                                             | Replace thyatron tube.<br>Check grid bypass capacitor.<br>Check associated Phase-<br>Shift Network and replace if<br>spare available.                                                                                |

100  
100  
100  
34.  
1100

TABLE 3-1. TROUBLESHOOTING CHART - Continued

| <u>Symptom and<br/>Waveform at<br/>First Choke</u>                                                   | <u>Possible Cause</u>                                                                                | <u>Remarks</u>                                                                                                                                                                                                           |
|------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DC output voltage varies excessively with changes in load. Amplitude of all phases vary identically. | Defective filament transformer T302.<br>Defective Correction Amplifier.                              | Check filament voltage on thyratrons. Check connections on Correction Amplifier connectors. Check Correction Amplifier.                                                                                                  |
| DC output voltage varies excessively with changes in load. Only one phase varies incorrectly.        | Defective thyatron tube.<br>Defective plate transformer T301.<br>Defective Grid Phase-Shift Network. | Replace thyatron tube. Check for equal voltage variation on T301 secondary windings as load is varied. Adjust GRID CONTROL potentiometer on Grid Phase-Shift Network of defective phase. Check Grid Phase-Shift Network. |
| Excessive output ripple. Waveform normal.                                                            | Defective filter capacitor and/or reactor.                                                           | Test all capacitor bank fuses with ohmmeter. If blown fuse found, replace capacitor bank. Check reactors with accurate, low-range ohmmeter, replace with spare if available.                                             |
| Excessive output ripple. Waveforms show one or more phases at low amplitude or completely absent.    | Defective filament and/or plate transformer; thyatron tube(s), Grid Phase-Shift Network.             | Check transformers; replace tubes; check Grid Phase-Shift Network.                                                                                                                                                       |

## 3-6. REGULATION CHECK.

While it is possible to make a rough estimate of the static regulation of a dc power supply by observing the change on its output voltmeter, or one connected across its output terminals, as the load is varied from zero to maximum, it is necessary to employ the method shown in figure 3-2 to obtain a precise measurement of the regulation. The dc bucking voltage can be either an electronic unit, or a group of batteries connected in series to supply a dc potential larger than the output voltage of the power supply under test. The voltmeter should have a full scale range of 0 to 5 or 10 volts,



since it will be used to measure only the difference between two almost equal voltages. The balance adjustment is used to bring the meter needle to approximately midscale before testing so that deviation above or below the normal output of the supply under test can be observed.

The dummy load is selected to draw full load current at the nominal output of the supply. The difference between the voltmeter readings with the switch open and closed (allowing the needle to come to rest before reading) gives the static regulation in volts.

Dynamic regulation is measured by substituting a calibrated oscilloscope for the voltmeter in figure 3-2, and measuring the maximum deflection as a load of appropriate value is switched in and out of the circuit. The design values of regulation are given in Section I.

### 3-7. GRID PHASE-SHIFT NETWORK CHECK.

#### A. Full-Wave Type.

##### 1. Equipment Required.

The following test equipment and power sources are required for this test:

- a. Oscilloscope with provision for line synchronization.
- b. DC ammeter with range from 0 to 25 milliamperes.
- c. A 115-volt, 60-cycle-per-second, 1-phase power source.
- d. A source of dc current variable from 0 to 10 milliamperes at approximately 10 volts.

##### 2. Test Procedure.

Proceed with test as follows:

- a. Connect vertical input terminals of oscilloscope to pins 6 and 7 of connector J201 on Network.
- b. Connect 115-volt ac line to pins 1 and 2 of connector J201.
- c. Adjust oscilloscope controls for multiple, 60 cps sine wave pattern on screen. Peaks of sine waves will be slightly flattened and approximately 60 volts peak-to-peak.
- d. Apply dc voltage, positive to pin 3 and negative to pin 4, and adjust current to 10 milliamperes. Pattern on oscilloscope screen will shift at least 90 degrees to the left with GRID CONTROL potentiometer R201 and GRID BALANCE potentiometer R204 set at midrange.
- e. Operation of potentiometer R201 can be checked by observing that waveform moves across screen as potentiometer is varied.
- f. Vary GRID BALANCE potentiometer R204 while observing waveform on oscilloscope, amplitude will vary with position of potentiometer.



g. Move oscilloscope vertical input connections to terminals 5 and 6 of connector J201. Repeat steps c and d. Step e does not apply as potentiometer R204 controls only one leg of output.

h. Disconnect all power sources and oscilloscope.

## B. Half-Wave Type.

### 1. Equipment Required.

The following test equipment and power sources are required for this test:

- a. Oscilloscope with provision for the line synchronization.
- b. DC ammeter with range from 0 to 25 milliamperes.
- c. A 115-volt, 60-cycle-per-second, 1-phase power source.
- d. A source of dc current variable from 0 to 10 milliamperes at approximately 10 volts.

### 2. Test Procedure.

Proceed with test as follows:

- a. Connect vertical input terminals of oscilloscope to pins 6 and 7 of connector J201 on Network.
- b. Connect 115-volt ac line to pins 1 and 2 of connector J201.
- c. Adjust oscilloscope controls for multiple, 60-cycles-per-second sine wave pattern on screen. Peaks of sine waves will be slightly flattened and approximately 60 volts peak-to-peak.
- d. Apply dc voltage, positive to pin 3 and negative to pin 4, and adjust current to 10 milliamperes. Pattern on oscilloscope screen will shift at least 90 degrees to the left with GRID control potentiometer R201 set at midrange.
- e. Operation of potentiometer R201 can be checked by observing that waveform moves across screen as potentiometer is varied.
- f. Disconnect all power sources and oscilloscope.

## 3-8. CORRECTION AMPLIFIER CHECK.

The following test equipment and power sources are required for this test:

- a. Ammeter, 0 to 50 milliamperes dc.
- b. One 1,000-ohm, 5-watt resistor.
- c. A 115-volt, 60-cycle-per-second, 1-phase power source.
- d. A 1.5-volt battery.

Proceed with test as follows:



- a. Remove Correction Amplifier from equipment.
- b. Connect pins 5 and 8 of connector J101 to 115-volt ac line through single pole switch.
- c. Connect meter and resistor in series between pins 1 and 2 of connector J102.
- d. Set line switch to On position and allow 1 minute for Amplifier to warm up.
- e. Connect 1.5-volt battery to pins 3 and 1 of connector J101 with positive terminal of battery going to pin 7. Ammeter should register current of approximately 1 milliampere.
- f. Reverse battery connections so that negative terminal of battery connects to pin 1 of connector J101. Ammeter should read approximately 35 milliamperes.
- g. Disconnect power sources and remove resistor and ammeter.

### 3-9. ADJUSTMENTS.

The following adjustments may require resetting during the normal use of the equipment. They should not be made unless a circuit component has been replaced and checks show that the circuit is not functioning correctly.

#### Single-Phase

|                    |   |                                                                                                                           |
|--------------------|---|---------------------------------------------------------------------------------------------------------------------------|
| Full-Wave Supplies | - | Saturable Reactor Current Adjustment<br>Thyratron Load Balancing Adjustment<br>OUTPUT VOLTAGE CONTROL Range<br>Adjustment |
|--------------------|---|---------------------------------------------------------------------------------------------------------------------------|

#### Three-Phase

|                    |   |                                                                                    |
|--------------------|---|------------------------------------------------------------------------------------|
| Half-Wave Supplies | - | Saturable Reactor Current Adjustment<br>OUTPUT VOLTAGE CONTROL Range<br>Adjustment |
|--------------------|---|------------------------------------------------------------------------------------|

#### Three-Phase

|                    |   |                                          |
|--------------------|---|------------------------------------------|
| Full-Wave Supplies | - | Same as Single-Phase, Full-Wave Supplies |
|--------------------|---|------------------------------------------|

It should be noted that the Saturable Reactor Current Adjustment and the Thyratron Load Balancing Adjustment in the three-phase supplies can involve resetting a particular control in one, or more of the Grid Phase-Shift Networks.

The Saturable Reactor Current Adjustment provides the means for setting the current in the saturable reactor at its optimum operating point.

The Thyratron Load Balancing Adjustment is the means by which load current is balanced in the two thyratron tubes of the full-wave circuit configuration.



The OUTPUT VOLTAGE CONTROL Range Adjustment sets the upper and lower limits for the OUTPUT VOLTAGE CONTROL.

### 3-10. SATURABLE REACTOR CURRENT ADJUSTMENT.

This adjustment is accomplished as follows:

- a. Connect oscilloscope at input to first choke to observe waveform of rectified voltage. Adjust oscilloscope sweep to display at least three cycles of line frequency. Train of waveforms should be consistently repetitive in shape, amplitude and period.
- b. Connect 0 to 25 milliamperes dc meter in series with dc input to Grid Phase-Shift Network, pin 3 or 4 of connector J201.
- c. Using a variable power transformer, set ac input voltage to maximum specified limit. Adjust OUTPUT VOLTAGE CONTROL for minimum dc output voltage and remove load from Supply.
- d. Adjust rheostat R201 for reading of approximately one-half milliamperes or minimum current at which thyatron will fire.

### 3-11. THYRATRON LOAD BALANCING ADJUSTMENT.

This adjustment balances the load in a pair of thyatrons and in so doing eliminates any ripple that exists as a result of such a load unbalance. The adjustment is made as follows:

- a. Connect oscilloscope at input to first choke to observe waveform of rectified voltage. Adjust oscilloscope sweep to display at least three cycles of line frequency. Train of waveforms should be consistently repetitive in amplitude.
- b. If waveshapes of a pair of thyatrons do not have the same amplitude, rheostat R204 should be adjusted for such a condition.

### 3-12. OUTPUT VOLTAGE CONTROL RANGE ADJUSTMENT.

The range of OUTPUT VOLTAGE CONTROL R2 is adjusted by the settings of rheostats R1 and R3. If the range is not as specified in Section I, proceed as follows:

- a. Set rheostat R2 to maximum clockwise position.
- b. Adjust rheostat R1 for maximum rated output voltage as read on voltmeter M1.
- c. Set rheostat R2 to maximum counterclockwise position.
- d. Adjust rheostat R3 for minimum rated output voltage as read on voltmeter M1.







OUR WARRANTY: N J E Corp. warrants each power supply manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replacing any defective parts thereof, except tubes and fuses in "standard-grade" models. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and which upon our examination is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.